

WO 00/74040

THIN MAGNETIC MEDIUM READ HEAD

RELATION TO PREVIOUS APPLICATION

This application claims priority to provisional patent application serial no.

5 60/136,603 filed on May 27, 1999.

FIELD OF THE INVENTION

The present invention relates to magnetic medium read heads and a methods of making such heads.

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BACKGROUND OF THE INVENTION

Magnetic card readers have been widely used in many industries for magnetic strip reading. The advent of the global computer communications network, the Internet, and the growing use of private computer networks by banks and other financial institutions have created an even greater demand for small, lightweight and compact devices that can be used by individual consumers and corporate end-users to gain access to the myriad resources available on such networks. In an effort to satisfy the growing demand for access to computer communication resources via compact devices, such as, PCMCIA cards, devices contained in 3 ½ inch floppy disk sized packages, PIM's (Personal Information Managers), mobile phones, and HPC's (handheld PC's), the developers of electronic devices have been actively investigating ways to miniaturize the components used in the compact devices that are in constant demand by consumers and other end-users. One of the components that is useful for the creation of smaller, compact devices is a thin, low cost magnetic medium read head. Such a device lends itself to incorporation in products with a thin form factor. Unfortunately, the creation of smaller devices often entails greater manufacturing costs. As the need has grown for a greater variety of such devices, there has been a growth in the demand for smaller components and better manufacturing processes that permit components to be produced at lower costs and which provide performance that is better than or comparable to their larger counterparts.

Prior art magnetic read heads for reading magnetic stripes or magnetic tape are typically thicker in the dimension measured perpendicular to the plane of the

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magnetic medium to be read than they are in a plane parallel to the magnetic medium. Fig. 1a illustrates a magnetic read head of conventional construction. The read head 10 is comprised of cores 12 that are shown in the illustration to be constructed of multiple plates. Wire coils 14 surround a portion of the cores 12. The 5 core/coil assemblies are fixed in a housing 15, indicated by the dashed outline, so that there is a gap 16 between opposing portions of the cores 12. As can be seen in Fig. 1a, the cores 12 generally define a plane, hereinafter the "core plane." In the case of conventional heads, the core plane is parallel to the 'z' and 'x' axes (or the z-x plane) shown in the figure. Similarly, the coils 14 each have a central axis, or 10 centerline. The centerlines of the coils generally define a plane, hereinafter the "coil plane." Again, in the case of conventional heads, the coil plane is parallel to the z-x plane. The gap 16 is defined herein to be in a plane on the surface of the head, the "gap plane," parallel to the 'y' and 'x' axes (or the y-x plane). The gap plane is then perpendicular to the core plane and the coil plane in conventional heads.

15 Fig. 1b illustrates a conventional prior art read head 10 in relationship to a magnetic medium. In this case the medium illustrated is a magnetic tape 18. As shown, the gap 16 is proximate the magnetic tape 18. In other words, the gap plane is parallel to the plane generally defined by the magnetic tape, hereinafter the "magnetic medium plane," which is also parallel to the y-x plane. It is evident that a 20 head of conventional construction, with the core plane perpendicular to the gap plane, will have considerable thickness in the "z" dimension. The smallest "z" dimension known in the art, for a head employing the conventional geometry discussed above, is approximately 0.26 inches (6.66 mm). A head of this thickness is inapplicable to many electronic package designs whose form factors call for an 25 even thinner "z" dimension.

For the foregoing reasons, there is a need for a thin magnetic read head wherein the read head is very thin in the "z" dimension, as illustrated in Figs. 2 and 3, and a process for inexpensively making such a read head.

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SUMMARY OF THE INVENTION

The present invention is directed to a thin magnetic medium read head, and a process for manufacturing the read head, wherein the gap plane of the head is parallel to the core plane or the coil plane of the head, and these planes are parallel

to the magnetic medium plane. Because the medium to be read is thin but long and wide, making the read head nearly as long or wide parallel to the magnetic medium does not present a size problem in a very small device, while making the read head thick, perpendicular to the magnetic medium, greatly increases the necessary size of
5 the device. Thus, a thin read head – thin in the dimension perpendicular to the magnetic medium (which, by definition herein, is perpendicular to the gap plane, core plane and coil plane) -- satisfies the current and foreseeable needs for miniaturized components in small, inexpensive electronic devices incorporating magnetic medium reading capabilities.

10 In accordance with one embodiment of the invention, left and right core pieces are cut and formed from magnetic material. A joggle bend, or offset, is formed in the top portion on one end of the core pieces to a desired angle depending on the thickness of a wire coil to be placed on the core piece. The core pieces are heat-treated using a desired temperature cycle and gas environment to recover their
15 magnetic properties after they have been fabricated. Magnetic coils are wound around one or both of the core pieces, forming core assemblies, to achieve the desired degree of induction from magnetic fields in the core pieces. Two mirror image brackets are formed from a non-magnetic material, and a plurality of slots are cut into each bracket to a desired depth and length. The core assemblies are
20 inserted edgewise into the slots of the two brackets and bonded to the brackets by a bonding agent. Wire leads from the coils on the core pieces are fed out of each bracket for further electrical connection. Once the core pieces are bonded to the brackets, the face of each bracket, and the edges of the core pieces contained therein, are machined flat to establish a bonding surface. A bonding agent is then
25 applied to the bonding surface of each bracket and the mirror image brackets are bonded to one another with a non-magnetic foil of a desired thickness disposed between the bonding surfaces of the brackets to establish a gap between opposing core pieces. The entire assembly is cured at a preferred temperature and pressure to create a unitized structure. After curing, the unitized structure is cut along planes
30 parallel to the core planes or coil planes into separate heads. The heads are ground or lapped to the desired thickness. As the head is ground and lapped, the top portion of each core piece contained within the head will be exposed. The exposed top portion contains the gap that will be in contact with the magnetic stripe on a card

or other magnetic media. The head is lapped to a contour that allows for the optimum contact between the gap and the magnetic media. After contouring, the head may be mounted in a card reader by various methods.

Another embodiment of the present invention is a two track read head. A flat
5 flexible cable is electrically connected to the coil wires of two core assemblies placed end to end, thus forming dual core assemblies. The dual core assemblies are inserted into slots in brackets. The fabrication procedure described above is duplicated. Each head then has two gaps and electrical connection to related circuitry is made through a portion of the flexible cable extending from an end of
10 each head.

An aspect of the invention is the overall thinness in the "z" dimension, i.e., perpendicular to the gap plane. In a preferred embodiment, the thinness is approximately 0.049". While an alternative embodiment has an overall thinness of 0.020".

15 Another aspect of the invention is that it has a small aspect ratio. The ratio of the "z" dimension of a preferred embodiment to the "y" or "x" dimension is approximately 0.073, while an alternative embodiment has an aspect ratio of 0.03.

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BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1a is an oblique view of a prior art read head.

Fig. 1b is an oblique view of a prior art read head in contact with a magnetic tape.

Fig. 2 is an oblique view of a single track read head.

25 Fig. 3 is an oblique view of a dual track head.

Fig. 4 is an oblique view of the left and right core pieces without a joggle.

Fig. 5 is an oblique view of the left and right core assemblies.

Fig. 6 is an oblique view of a bracket for a single track head.

Fig. 7 is a top view of a portion of a bracket loaded with a core assembly.

30 Fig. 8 is an end view of the unitized structure.

Fig. 9 depicts the planes along which the unitized structure is divided.

Fig. 10a is an oblique view of a single track read head.

Fig. 10b is an oblique view of an alternative embodiment of a single track read head.

Fig. 11 is an oblique view of a dual track head bracket.

5 Fig. 12 is a plan view of a flexible printed wiring board.

Fig. 13a is a plan view of a portion of a dual track head bracket loaded with a dual core assembly.

Fig. 13b is an elevation view of a dual track head bracket loaded with a dual core assembly.

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DETAILED DESCRIPTION OF THE INVENTION

Fig. 4 shows a left core piece 100 and a right core piece 200, each piece having corresponding thickness "t", width "w" and length "l". The left core piece 100 and the right core piece 200 are manufactured from a magnetic alloy. In a preferred embodiment, the magnetic alloy typically consists of 80% nickel and 20% iron, referred to in the art as Permalloy, which is preferred due to its high permeability, low coercivity, high resistivity and high saturation induction. However, any other magnetic alloy known by those skilled in the art of creating magnetic read heads may be used in the core pieces 100, 200 to achieve the desired design and electrical signal characteristics.

The core pieces have three separate geometrical sections. Bottom sections 101, 201, middle sections 102, 202 and tapered top section 103, 203. In a preferred embodiment of the invention, the thickness "t" of cores 100, 200 is .010", the overall width "w" is .093", and the overall length "l" is .30". However, smaller dimensions are useful with the principal limitation being the components become very fragile and difficult to handle as the dimensions are reduced, in particular the thickness "t". An alternative embodiment employs a core with a thickness of .005".

Figure 5 depicts the core pieces 100, 200 having a joggle bend in the tapered portions 103, 203. (A joggle being a compound bend designed to offset portions of a flat, or planar, material, and keep the resultant planes parallel to one another.) The tapered section 103, 203 of the core pieces 100, 200 shown bent to an angle "A" of 36 degrees. However, the degree to which tapered sections 102, 203 are bent

102, 202. The joggle dimension 111, 211 is 0.036 inches in a preferred embodiment, although this dimension may vary according to the thickness of the wire coil and clearance requirements for the later machining steps. After forming, the core pieces 100, 200 are heat treated using a desired temperature and gas environment to recover their magnetic properties.

5 Fig. 5 also shows the core pieces 100, 200 having an AWG 49 copper wire, commonly referred to as magnetic wire, winding or coil 110, 210 wound about middle sections 102, 202. The number of turns and wire gauge required in the coils 110, 210 will vary depending in part on the core materials, the strength of the magnetic flux passing through the cores, and whether only one or both cores are wound with coils. Copper wire is typically used in read heads, but other applicable wire materials are known in the art. Wire of AWG 56 is known in the art and may be used to form coils 110, 210.

10 In Fig. 6, a left bracket for a single track head 400 is shown generally. In a preferred embodiment of the present invention, the bracket 400 is made from aluminum 6061, commonly referred to as Al 6061, although other materials may be used to make the brackets such as plastic, ceramic or other non-magnetic materials known by those skilled in the art of producing magnetic read heads. The bracket 400 has a bonding face 401 with two raised edges 402a and 402b with a plurality of opposing slots 403a and 403b. The overall dimensions of bracket 400 and the spacing of the slots 403a, 403b are variable depending on the machining techniques employed as will be obvious to one skilled in the art. However, the depth 404 of the slots 403a, 403b, is nominally the same as the width "w" of cores 100, 200 for reasons that will become apparent below. The width 406a of slots 403a is slightly larger than the joggle dimension 111, 211 of cores 100, 200. The width 406b of slots 403b is slightly larger than the thickness "t" of the cores 100, 200. A right bracket 500 (not shown in Fig. 6) is a mirror image of bracket 400.

15 Fig. 7 is a top view of a portion of bracket 400 with showing a left core assembly 120, comprised of a left core 100 and left coil 110, inserted edgewise in opposing slots 403a, 403b. The tapered section 103 is inserted in slot 403a, and the bottom section 101 is inserted in slot 403b. The coil assembly 120 is then bonded in place by epoxy or other bonding agent known in the art. After the bonding agent has cured, the bonding face 401 is machined flat, as by lapping or a similar process,

such that the core assembly edges 121 of the core assembly 120 and the bonding face 401 are co-planar. This process is repeated using a mirror image right bracket 500 and right core assemblies 220 comprised of right cores 200 and coils 210. (not shown)

5 Refer now to Fig. 8. A thin layer of foil 450 is secured between bonding faces 401 and 501 with a bonding agent. The foil 450 determines the thickness of gap 16 between opposing top sections 103, 203 of core assemblies 120, 220 contained within the bonded brackets as indicated by the dashed lines. The foil 450 may be made from copper, mica, or any other non-magnetic material known to those skilled
10 in the art of making electromagnetic reader heads. The thickness of the foil is 0.0005 inches in a preferred embodiment of the invention. However, gap forming foils ranging from 0.0001 to 0.0015 inches are known in the art.

Refer now to Fig. 9. After curing of the bonding agent, the unitized structure 598 comprising the brackets 400, 500 and the opposing pairs of core assemblies
15 120, 220 are divided into individual read heads 600 along planes 599 parallel to the y-x plane, preferably by cutting.

Refer now to Fig. 10a. After separating, individual heads 600 are machined by various grinding, lapping or polishing processes to finished dimensions. As the heads are machined thinner in the "z" dimension, the tapered sections 103, 203 are
20 partially exposed. This exposed portion of the sections 103, 203 contains the gap 16. The gap face 601 containing the gap 16 generally defines the gap plane of the read head as discussed above in the Background section. The gap face 601 is further machined to a desired contour that allows for optimum contact between the gap and the magnetic medium. Bearing in mind that the coils 110, 210 contained
25 within the head have a thickness in the "z" dimension, it can now be better appreciated the need for a joggle, or offset, in the core pieces. This permits machining to expose the tapered sections 103, 203 without damaging the coils.

The present invention results in a read head with a very small dimension in the "z" dimension relative to prior art read heads because the core assemblies 120,
30 220 have been in effect rotated 90 degrees compared to the orientation of core assemblies within conventional read heads (Refer to Figs. 1a and 1b.)

An alternative embodiment is illustrated in Fig. 10b. In this case the core pieces do not have a joggle, or have a joggle of lesser thickness than the coils,

formed in tapered sections 103, 203. The machining steps to expose the top sections, are restricted to the portion of head 600 not containing the coils. A head fabricated in this manner can be used to read a magnetic medium such as a magnetic stripe located proximate an edge of a credit card. Because the thickness 5 of the card does not overlap the thickest point of the read head, the total thickness of the final device with a card slot can be thinner still.

An alternative embodiment of the present invention is a two track read head 700 shown generally in Fig. 3. The two track embodiment is similar in most respects to the single track embodiment previously disclosed. In a preferred embodiment, it 10 includes a flexible printed wiring board (PWB) 710a and 710b to provide electrical connection to the coils contained within the head. Gaps 16 are positioned relative to a magnetic medium (not shown) so that two tracks of encoded information can be read simultaneously.

Fig. 11 depicts left bracket 800. The bracket 800 is essentially a double width 15 version of bracket 400 described above, providing room in the slots 803 for receiving two core assemblies inserted end-to-end, i.e., tapered section-to-tapered section. A mirror image to left bracket 800 is right bracket 900 (not shown).

Fig. 12 is a plan view of flexible PWB 710a. The flexible PWB is constructed of material and by techniques well known in the art. Electrical traces 711 are 20 electrically connected to the wires forming coils 110, 210 (not shown) at locations identified by notches 712. The electrical traces conduct signals to pads 713 for further electrical connection to related circuitry. Flexible PWB 710b (not shown) is a mirror image of flexible PWB 710a.

Fig. 13a is a plan view of a portion of bracket 800 with slots 803 loaded with a 25 dual core assembly 1000 comprised of core assemblies 120, 220 and flexible PWB 710a connected to core assemblies 120, 220. Fig. 13b is a side view of the loaded bracket 800. The mirror image right bracket 900 is similarly loaded with dual core modules 1002 (not shown) which are mirror images of core modules 1000. The modules 1000, 1002 are then bonded to their respective brackets as described 30 previously.

The remaining manufacturing steps are the same as in the previously described single-track read head. The result is the dual-track read head illustrated in

Fig. 3. A single-track read head may be constructed using the flexible PWB described.

It will be apparent to those skilled in the art that other shapes and arrangements of the cores and coils are readily applicable to the invention with minor 5 modifications. For example, it is known in the art to make the cores in a generally horseshoe, or U-shaped. Such a shape will still generally define a plane analogous to the core plane defined above. A coil or coils wound about a horseshoe shaped core will still have an axial centerline that can also define a coil plane parallel to the gap plane. Therefore, a horseshoe shaped core assembly is useful in the present 10 invention as long as it is adaptable to the planar geometric relationships disclosed herein that provide for a thin read head. Similarly, only one of two cores may be wound with a coil.

Single or dual-track heads constructed according to the methods described herein can be used to construct heads with a "z" dimension, or thinness of 15 approximately 0.049 in a preferred embodiment while the thinness of an alternative embodiment is 0.020.

A useful means of comparing the prior art with the present invention is to consider dimensional aspect ratios. The thinness aspect ratios of particular interest are those of the "z" dimension divided by either the "x" or "y" dimensions of the head, 20 in other words, the z/x and z/y thinness aspect ratios. For thin read heads, having a small aspect ratio is preferable since that implies the thinness of the head in the "z" dimension is small thus making such a head more suitable for use in compact electronic devices. A preferred embodiment has an aspect ratio of approximately 0.073, while an alternative embodiment has an aspect ratio of 0.03. Whereas, the 25 smallest aspect ratio known is the prior art is approximately 1.15.

We claim:

1. A coil-type magnetic medium read head having at least one core, the core substantially defining a core plane, and a Z thinness dimension perpendicular to the core plane, wherein the Z thinness dimension is between .26 inches and .020 inches.
- 5 2. The read head of claim 1 wherein the Z thinness dimension is between 0.10 inches and .020 inches.
3. The read head of claim 1 wherein the Z thinness dimension is approximately .049 inches.
4. The read head of claim 1 wherein the Z thinness dimension is approximately .020 inches.
- 10 5. A coil-type magnetic medium read head having at least one coil, the coil substantially defining a coil plane, and a Z thinness dimension perpendicular to the coil plane, wherein the Z thinness dimension is between .26 inches and .020 inches.
6. The read head of claim 5 wherein the Z thinness dimension is between 0.10 inches and .020 inches.
- 15 7. The read head of claim 5 wherein the Z thinness dimension is approximately .049 inches.
8. The read head of claim 5 wherein the Z thinness dimension is approximately .020 inches.
- 20 9. A thin coil-type magnetic medium read head for reading a magnetically coded medium having an X dimension parallel to a gap plane, a Y dimension parallel to the gap plane and perpendicular to the X dimension, and a Z dimension perpendicular to the gap plane and the X and Y dimensions, wherein the thinness aspect ratio of Z/X is less than 1/1 and the thinness aspect ratio of Z/Y is less than 1/1.
- 25 10. The head of claim 9 wherein either the Z/X or the Z/Y thinness aspect ratio is less than 1/5.
11. The head of claim 9 wherein either the Z/X or the Z/Y thinness aspect ratio is less than 1/12.
12. The head of claim 9 wherein either the Z/X or the Z/Y thinness aspect ratio is less than 1/30.
- 30 13. A thin coil-type magnetic medium read head wherein a gap plane is substantially parallel to a coil plane.
14. A thin coil-type magnetic medium read head wherein a gap plane is substantially parallel to a core plane.

15. A process for making a thin magnetic medium read head, the head having at least one coil therein, the coil defining a coil plane, comprising:

- (a) loading a slot in a left bracket with a left core assembly and a slot in a right bracket with a right core assembly;
- 5 (b) bonding the left core assembly and the right core assembly to its respective bracket with a bonding agent;
- (c) machining on the left bracket a left bonding surface proximate the slot therein, and on the right bracket a right bonding surface proximate the slot therein, whereby an edge of each core assembly in its respective slot is flush with its
10 respective bonding surface;
- (d) positioning the left and right brackets with a foil placed between each bonding surface, and the left and right brackets being positioned such that the left core assembly is substantially co-planar with the right core assembly;
- 15 (e) bonding the bonding surfaces and foil together with a bonding agent to create a unitized structure with sufficient pressure that the foil forms a gap between the left core assembly and the right core assembly substantially equal to the thickness of the foil; and
- (f) machining a side of the unitized structure substantially parallel to a coil plane whereby a portion of the core assembly is exposed thus exposing the gap.

20 16. A process for making a plurality of thin magnetic medium read heads, each head having at least one coil therein, the coil defining a coil plane, comprising:

- (a) loading each of a plurality of slots in a left bracket with a left dual core assembly, and a plurality of slots in a right bracket with a right dual core assembly;
- 25 (b) bonding the left dual core assemblies and the right dual core assemblies to their respective brackets with a bonding agent;
- (c) machining on the left bracket a left bonding surface proximate the slots therein, and on the right bracket a right bonding surface proximate the slots therein, whereby an edge of each left and right dual core assembly in its respective slot is flush with its respective bonding surface;
- 30 (d) positioning the left and right brackets with a foil placed between each bonding surface, and the left and right brackets being positioned such that each left dual core assembly is substantially co-planar with a corresponding right dual core assembly;
- (e) bonding the left and right bonding surfaces and foil together with a bonding agent to create a unitized structure with sufficient pressure that the foil forms
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a plurality of gaps, each gap between the left dual core assembly and the right dual core assembly being substantially equal to the thickness of the foil;

(f) dividing the unitized structure into individual heads;

(g) machining a side of each head substantially parallel to a coil plane

5 whereby a portion of the left and right dual core assemblies therein are exposed, thus exposing one or more of the plurality of gaps.

17. A process for making a thin magnetic medium read head, the head having at least one core therein, the core defining a core plane, comprising:

10 (a) loading a slot in a left bracket with a left core assembly and a slot in a right bracket with a right core assembly;

(b) bonding the left core assembly and the right core assembly to its respective bracket with a bonding agent;

(c) machining on the left bracket a left bonding surface proximate the slot therein, and on the right bracket a right bonding surface proximate the slot therein, whereby an edge of each core assembly in its respective slot is flush with its 15 respective bonding surface;

(d) positioning the left and right brackets with a foil placed between each bonding surface, and the left and right brackets being positioned such that the left core assembly is substantially co-planar with the right core assembly;

20 (e) bonding the bonding surfaces and foil together with a bonding agent to create a unitized structure with sufficient pressure that the foil forms a gap between the left core assembly and the right core assembly substantially equal to the thickness of the foil; and

(f) machining a side of the unitized structure substantially parallel to a 25 core plane whereby a portion of the core assembly is exposed thus exposing the gap.

18. A process for making a plurality of thin magnetic medium read heads, each head having at least one core therein, the core defining a core plane, comprising:

30 (a) loading a plurality of slots in a left bracket with a left dual core assemblies, and a plurality of slots in a right bracket with a right dual core assemblies;

(b) bonding the left dual core assemblies and the right dual core assemblies to their respective bracket with a bonding agent;

(c) machining on the left bracket a left bonding surface proximate the 35 slots therein, and on the right bracket a right bonding surface proximate the slots



therein, whereby an edge of each left and right dual core assembly in its respective slot is flush with its respective bonding surface;

5 (d) positioning the left and right brackets with a foil placed between each bonding surface, and the left and right brackets being positioned such that each left dual core assembly is substantially co-planar with the corresponding right dual core assembly;

10 (e) bonding the left and right bonding surfaces and foil together with a bonding agent to create a unitized structure with sufficient pressure that the foil forms a plurality of gaps, each gap between the left dual core assembly and the right dual core assembly being substantially equal to the thickness of the foil;

15 (f) dividing the unitized structure into individual heads;

 (g) machining a side of the unitized structure parallel to a core plane whereby a portion of the left and right dual core assemblies therein are exposed, thus exposing one or more of the plurality of gaps.

19. A thin magnetic medium read head manufactured by a process comprising the steps in claim 15.

20. A thin magnetic medium read head manufactured by a process comprising the steps in claim 16.

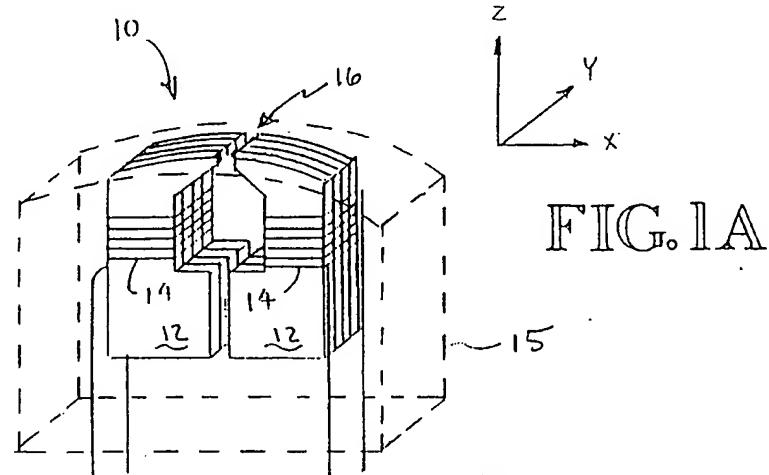


FIG. 1A

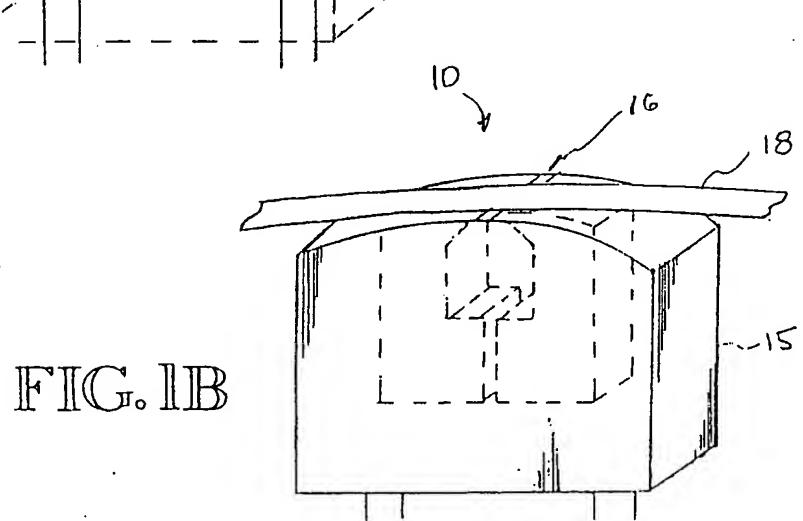


FIG. 1B

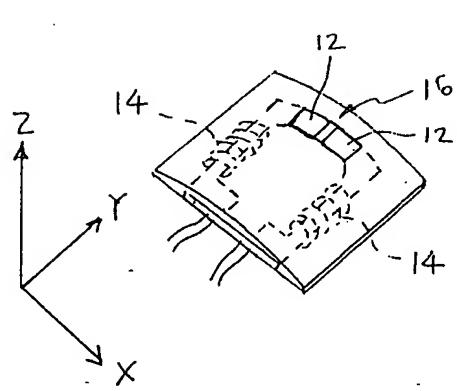


FIG. 2

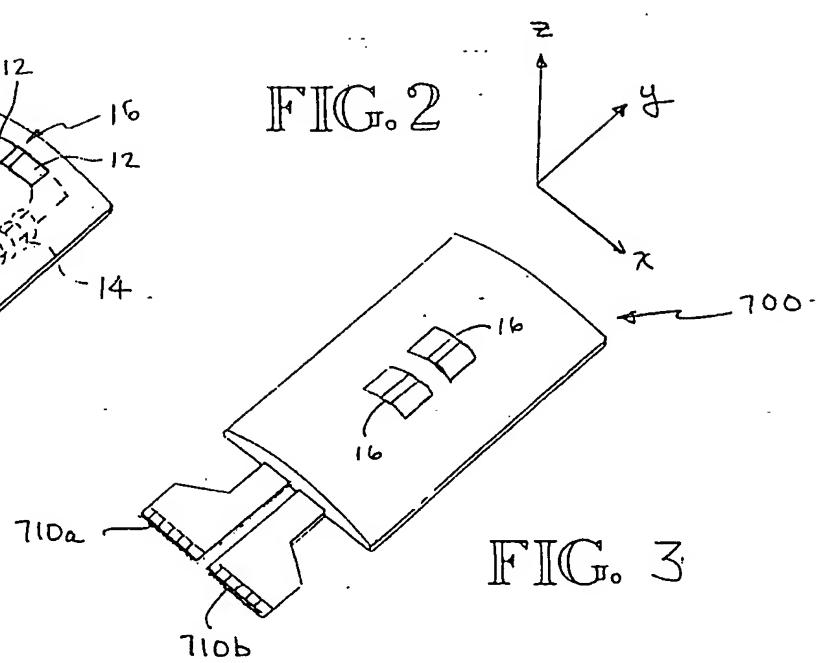
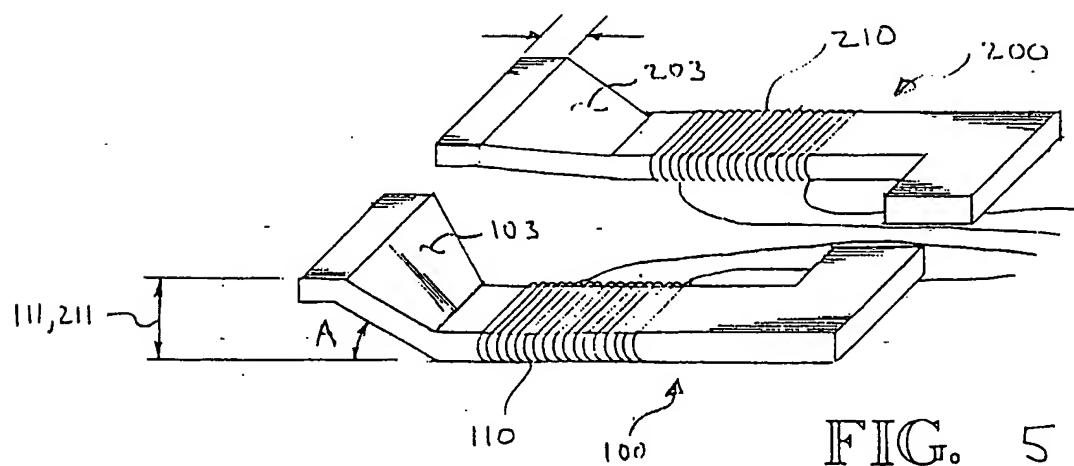
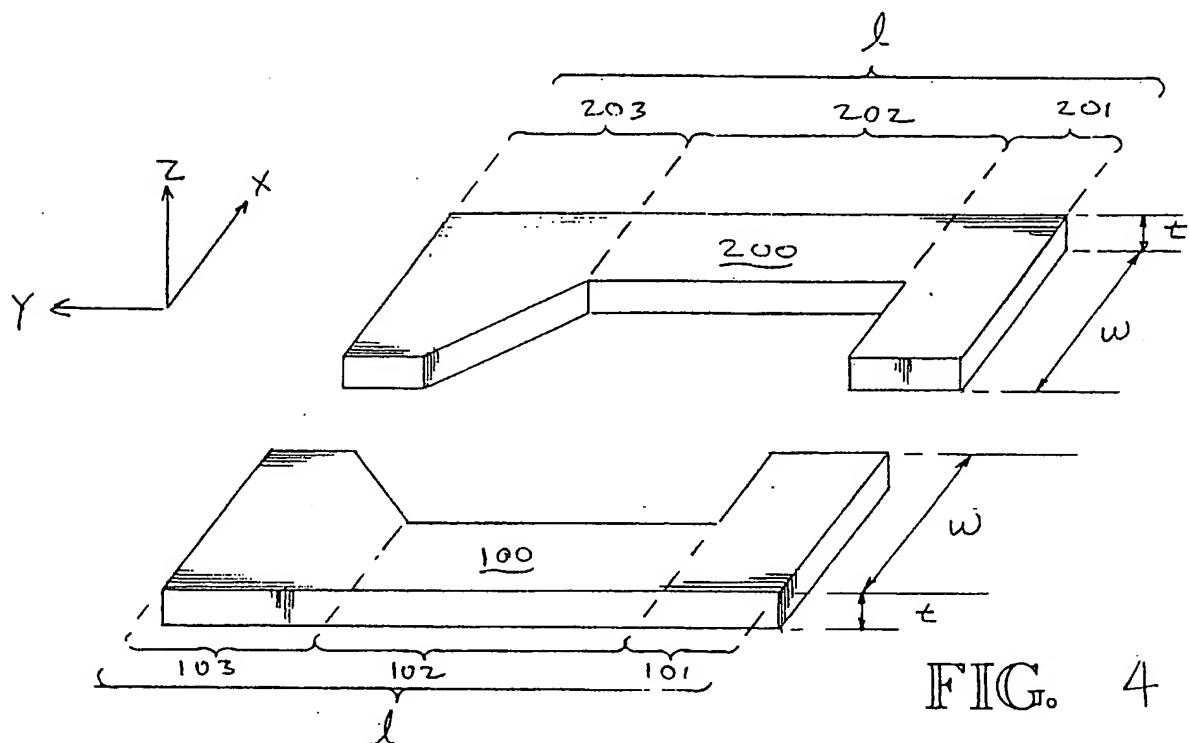
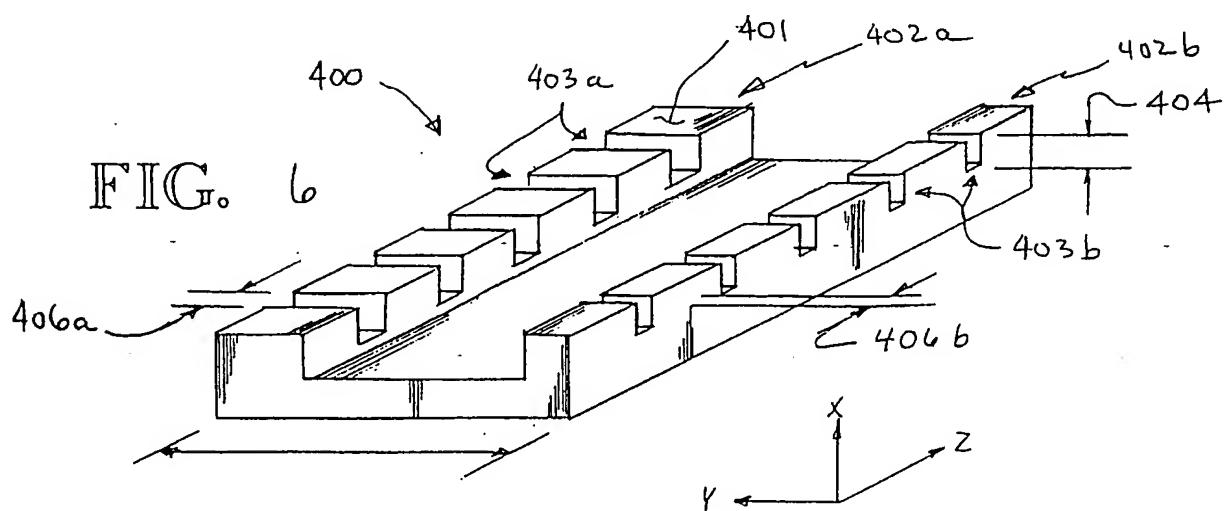
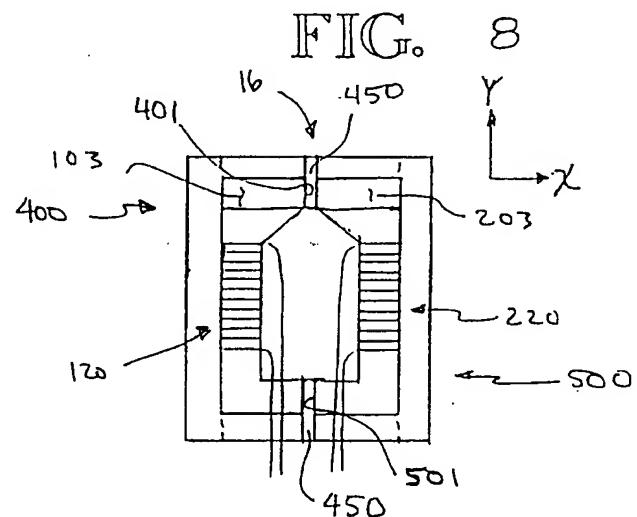
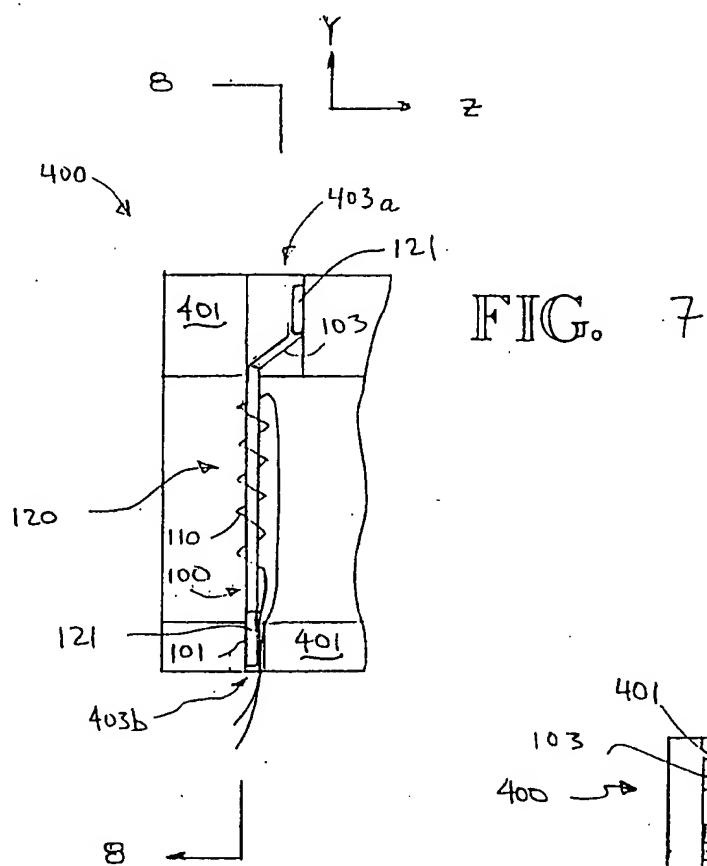


FIG. 3

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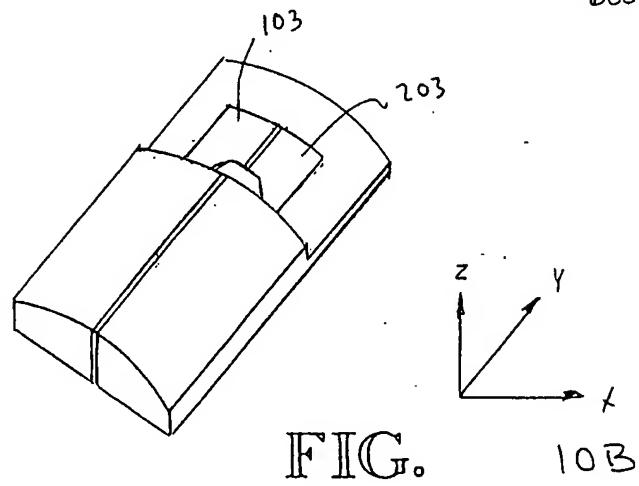
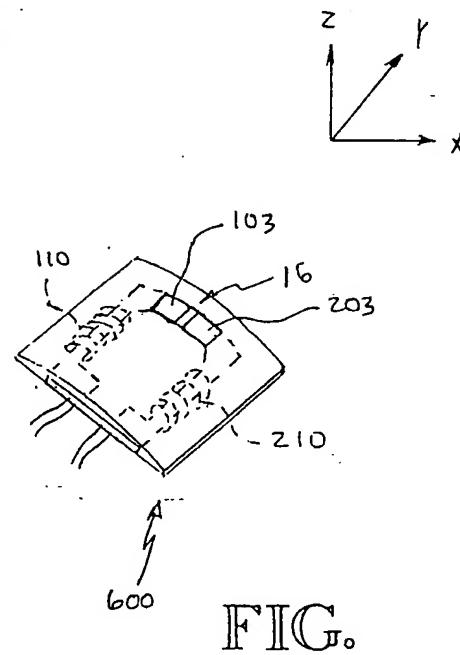
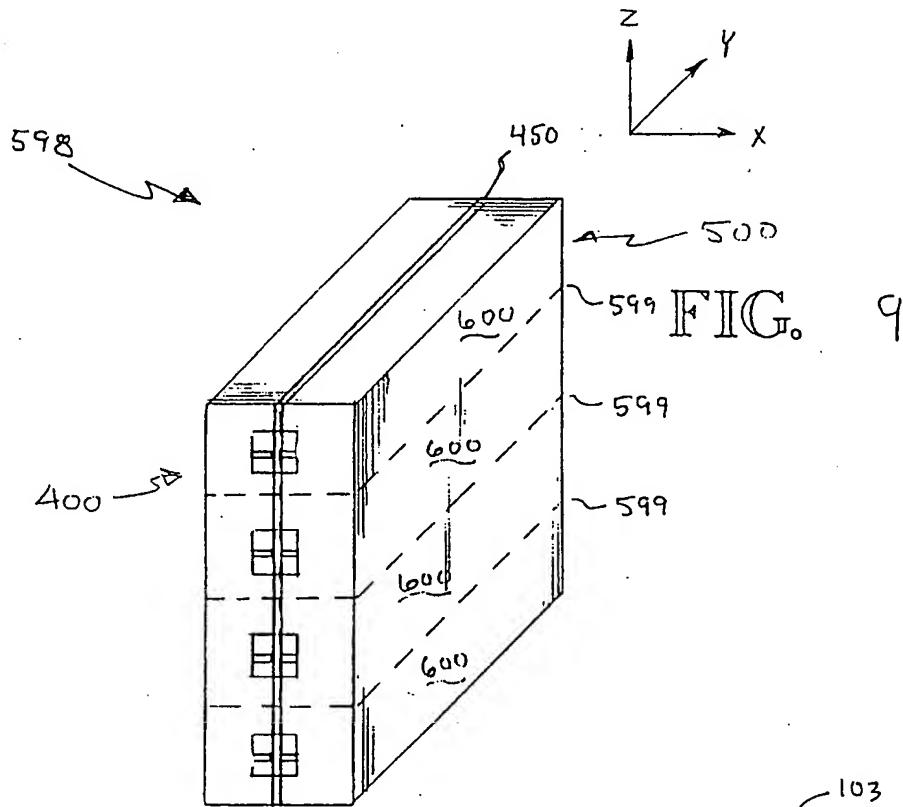


FIG. II

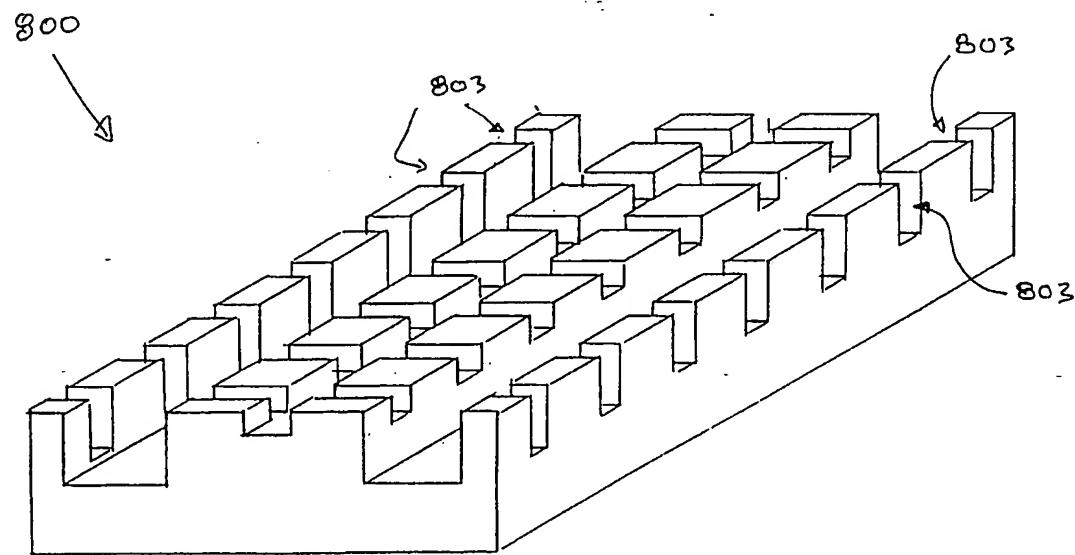


FIG.12

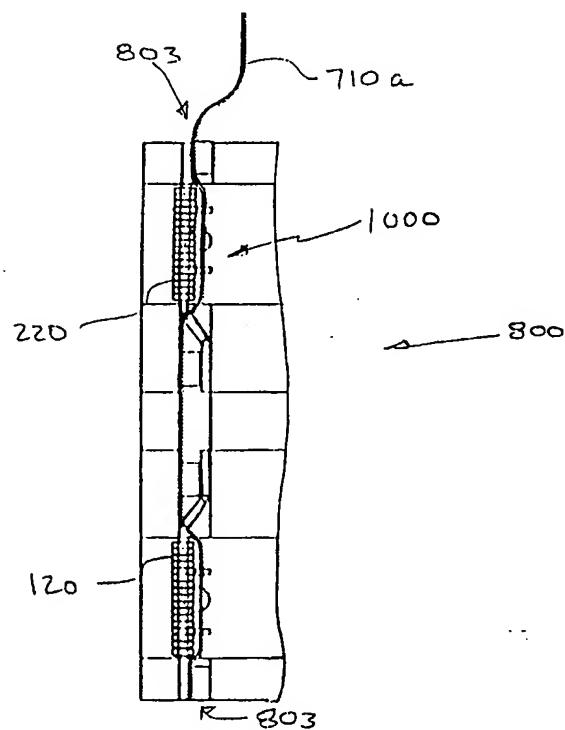
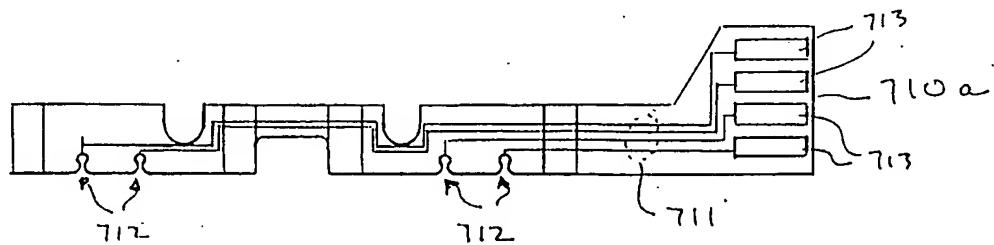


FIG.13A

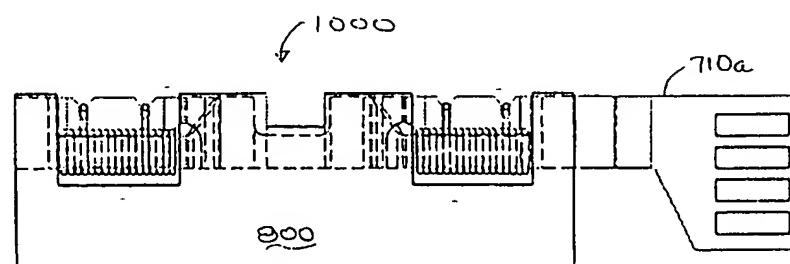


FIG.13B

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/14449

A. CLASSIFICATION OF SUBJECT MATTER		
IPC(7) :G11B 5/147 US CL :360/126, 121, 122, 125, 119 According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED		
Minimum documentation searched (classification system followed by classification symbols) U.S. : 360/126, 121, 122, 125, 119		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched NONE		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) NONE		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4,839,763 A (MATSUZAWA) 13 June 1989, figure 1	1-20
X	US 4,816,949 A (YAMADA et al) 28 March 1989, figure 3	1-20
X	US 4,811,146 A (NIWA) 07 March 1989, figures 1 and 3-5	1-20
X	US 4,819,113 A (KUBOTA et al) 04 April 1989, figures 1 and 5	1-20
X,E	US 6,072,669 A (INDECK) 06 June 2000, figures 1, and 4-6	1-20
<input type="checkbox"/> Further documents are listed in the continuation of Box C. <input type="checkbox"/> See patent family annex.		
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